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PERCENTAGES OF ASH, TOTAL SULFUR AND SULFUR FORMS IN U.S.A. COALS

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ABSTRACT

The frequency distributions of ash and sulfur percentages for coals of the United States are presented graphically, including coals from the various coal producing counties and coal beds of 30 states plus Alaska. Coals of all ranks are included. The range of ash and sulfur percentages and their relative frequency are shown by the graphs.

The percentages of pyritic, organic and sulfate sulfur are shown versus total sulfur, for coals of Ohio and Illinois.

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This paper discusses the frequency distribution of ash and sulfur contents of coals of the United States. The coal reserves of America are so vast and diversified that the subject can be presented in only a general way in this short paper. However, the summarized technical information which follows should provide a useful statistical background for the study of particular phases of ash and sulfur in coal.

The publications of Federal and State agencies, and particularly the publications of the United States Bureau of Mines, contain the analyses of tens of thousands of samples of coal which have been collected and analyzed by carefully prescribed methods. Many of these were channel samples cut across the coal bed in the mine, or drill-core samples, both of which represent the natural coal as it lies in the ground.

However, a large proportion of the analyses, particularly those published in recent years, are of samples taken at mine tipples as the coal was being loaded into railroad cars or trucks, or of delivered coal. These tipple or delivered samples represent commercial shipments of coal which in most cases has been sized, cleaned or otherwise prepared for market.

Ash and Sulfur of Typical U. S. Coals

The number of published coal analyses is so great that the study of frequency distribution will be greatly facilitated by using a series of typical coal analyses. The most convenient reference is "Typical Analyses of Coals of the United States" (1) published in 1942 and reprinted in 1954. This contains 737 analyses which were carefully selected to exemplify the analysis of coal mined and shipped in each coal-producing county of the United States, and where feasible, coal from each bed in each county.

These analyses were selected to represent typical commercial shipments at that time, and some of the coal had been mechanically cleaned. When more than one size was being prepared, the average analysis of the total coal shipped was computed from the analysis of each size that was sampled. It is these typical composite analyses which are graphed in Figures 1 and 2. (The original reference, in about 25% of the cases, also shows the range in analysis which could be expected in coals from a given county.)

It is seen that the ash content on the "as-received" basis peaks at 9% ash, and that 90% of the analyses fall within the limits of 2.5% to 13% ash. The sulfur content peaks at 0.6% but is a very skewed curve, and only 57% of the analyses fall within the limits of 0.2% to 1.4% sulfur.

In considering the distribution and range of ash and sulfur analyses shown in Figures 1 and 2, it should be kept in mind that these analyses include coals of all ranks, that is lignites, subbituminous and bituminous coals, and anthracites, occurring in 30 states plus Alaska.

It must also be kept in mind that these analyses were published in 1942, and were originally assembled for use under the Bituminous Coal Act of 1937, so they are about twenty years old. During the past twenty years, there has been a fourfold increase in the percentage of coal production that is mechanically loaded and a similar increase in the percentage that is mechanically cleaned. Also, there have been some changes in the mines and coal beds worked. Thus it might be supposed that the data shown in Figures 1 and 2 are obsolete. However, some of these changes tend to compensate for each other.

Ash and Sulfur in Federal Coal Purchases - 1956

No new study of typical coals of the U. S. has been published in recent years, but it will be interesting to compare the analyses of tipple and delivered samples of coal purchased by the Federal Government in a recent year. The most recent publication in this series contains the analyses of samples collected for the fiscal year 1956(2). This gives 1646 analyses of coals of all ranks, mined in 22 states plus Alaska. A large proportion of the samples represent screened sizes ranging from large lump to small slack, rather than the total coal from a mine. (The analyses of screened sizes from a given coal mine may vary substantially from each other.)

For most of the government coal purchases the bidders specify the analysis of the coal which they are offering, and the analysis guaranteed by the successful bidder becomes the standard of his contract. The deliveries are sampled and analyzed to determine whether the coal is of the quality guaranteed. The Federal Government purchased about 5 million tons of coal in fiscal year 1956, which was used chiefly for heating government buildings and installations. Such purchases represented about 1% of the total coal produced in the United States.

The analyses shown in Reference 2 and Figures 3 and 4 do not include coal purchased by the Tennessee Valley Authority, whose steam plants received 17,584,000 tons of coal during fiscal 1956.

The ash and sulfur contents on the dry basis of government purchases of various coal sizes in 1956 are shown in Figures 3 and 4. There is a striking similarity in the frequency distribution of ash and sulfur of these recent samples with the earlier analyses shown in Figure 1 and 2 (which represented the composites of coal sizes on an as-received basis).

The recent analyses peak at 6.5 to 9% ash, and 91% of the analyses fall within the range of 1-1/2% to 13% ash. As in the earlier analyses, the sulfur peaks at 0.6%, and has a very skewed curve, with 70% of the analyses falling within the limits of 0.2% to 1.4% sulfur. Thus the recent analyses show slightly cleaner coal, but are quite similar on the average to the earlier analyses.

It must be emphasized that none of the foregoing graphs are "weighted" with respect to the tonnage of coal represented. Thus in Figures 3 and 4, an analysis may represent anything from a single truck delivery of 1 to 5 tons, to the average of a year's receipts of a certain size coal from a certain mine, totalling more than 50,000 tons. Furthermore, Figures 3 and 4 do not include coal purchased for the two largest specific industrial uses, namely electric utilities and coke plants.

Figure 5 represents an attempt to compile sulfur percentage frequencies weighted for the tonnage of total bituminous coal produced in the eastern U. S. The data were obtained by multiplying the tonnage of coal produced in each bituminous-coal-producing county of the eastern half of the U. S. in 1953(3) by the "typical" sulfur for that county(1). This method will give only an approximation and the results may not be close to the true figures in some individual cases. However, when

a number of such results are combined, as in Figure 5, the figures should be indicative in a general way. In any case, the writer does not know of any other attempt to present the sulfur contents of such a large proportion of U. S. coal shipments.

Figure 5 indicates two peaks for sulfur content, with one at about 0.8% and the other at 1.3% sulfur. If the estimates are valid, 213 million tons or 50% of the bituminous coal shipped in the eastern half of the U. S. in 1953 was in the range of 0.5% to 1.4% sulfur content. (In that year, 119 million tons of good purity U. S. coals were used for making oven coke in the United States and Canada, or were exported overseas mostly for metallurgical uses.) Figure 5 also shows that substantial tonnages were shipped of coal in the 3-4% sulfur range (e.g., for power generation.)

The data in Figure 5 are not closely comparable with Figures 2 and 4, since Figure 5 shows only bituminous coals in the eastern half of the United States (because the data were computed for a special survey.) Excluded are all lignite, subbituminous coal and anthracite wherever produced in the U. S., and all bituminous coals mined in the western half of the U. S. Such excluded coal, most of which was moderate to low in sulfur content, amounted to 65 million tons, or 13% of the total U. S. coal produced in that year. No attempt has been made to estimate weighted tonnages by ash content for 1953 shipments.

Ash and Sulfur in Metallurgical Coals

The following items are of interest in connection with the purity of coals used for coke manufacture.

Analysis of Oven Coke in the U. S., 1943-45 and 1951-53(3, p. 226)

Year	Blast-Furnace Coke*		Foundry Coke	
	% Ash	% Sulfur	% Ash	% Sulfur
1943	9.7	0.8	8.1	0.6
1944	10.2	0.8	8.3	0.6
1945	10.5	0.8	8.6	0.6
1951	9.9	0.9	8.7	0.6
1952	9.9	0.9	8.7	0.6
1953	9.7	0.9	8.7	0.6

*1943-45 analyses include all coke other than foundry, and are presumed to be mostly blast-furnace coke.

When coal is coked, the average yield of coke plus coke breeze is about 75% of the weight of coal in the case of blast-furnace coke, and somewhat higher in the case of foundry coke. All of the ash remains in the coke and breeze, so that the ash content of coal used for making coke in 1953 evidently averaged slightly over 7%. The writer has found by graphic studies not presented here, that the sulfur percentage in oven coke is similar to but usually slightly lower than that in the coal used. Thus the coal mixtures coked in 1953 probably averaged slightly over 0.9% and 0.6% sulfur respectively for the two types of metallurgical coke.

In a series of reports investigating U. S. coals suitable for the production of metallurgical coke, either as mined or after beneficiation, the U. S. Bureau of Mines states(7):

> "According to present-day standards for metallurgical coal, many believe that, on the dry basis, the sulfur content of the coal should not exceed 1.25 percent and the ash 8 percent. Coal with more than this amount

of sulfur has been used for making metallurgical coke, especially when blended with coal containing less sulfur. In this series of reports, 1.25 percent sulfur is used as a gage to determine whether or not a coal can be used to produce metallurgical coke."

In any given industrial area, the maximum ash and sulfur percentages that will be acceptable in metallurgical coals will depend upon the purity and delivered cost of the available coking coals, the kind of iron ore used, etc.

Sulfur Forms in U. S. Coals

Three forms of sulfur are recognized in coal: (a) sulfur combined with iron (FeS_2) as pyrite or marcasite and known as pyritic sulfur, (b) sulfur combined with the coal substance as organic sulfur, and (c) small quantities of sulfate sulfur in the form of calcium sulfate or iron sulfate. Freshly mined unoxidized coal usually contains only a very small amount of sulfate sulfur(6).

Figures 6 and 7 show for Ohio and Illinois coals, the distribution of organic, pyritic and sulfate sulfur percentages versus total sulfur. It will be seen that organic sulfur amounts to 20 to 60% of the total in most coals from these states, that pyritic sulfur ranges from 40 to 80% in most cases, and that the sulfate sulfur is a very small part of the total. The writer has made similar graphs which are not presented here, of sulfur forms from certain other states including Iowa, Kentucky and Tennessee. In all of the cases studied, the sulfur in coals containing 0.5% sulfur or less was almost entirely organic, with pyritic sulfur beginning to show up at about 0.5 or 0.6% total sulfur.

The writer has prepared numerous other graphs for special purposes which show the frequency distribution of various coal constituents and physical properties by rank of coal, coal bed, geographical area, etc. However, no additional graphs will be presented here since readers will usually be interested in special cases which they can best select and graph for themselves.

Trends in Ash and Sulfur Contents

Not much systematic information has been published on broad trends in the ash and sulfur contents of commercial coal shipments. Since there are more than 8,000 coal mines operating in 27 states, and since most of these mines ship several sizes of coal differing in ash and sulfur contents, the collection and statistical treatment of such information would be very costly, and probably not worth the effort.

Leading coal producers intensively study the characteristics of their coal reserves, including washability by available methods, and they regularly test the quality of coal shipped. Large coal users study the characteristics of coals available to them and they may analyze shipments of coal received. Thus there is much information on coal ash and sulfur percentages in company files, which applies to specific cases.

The factors which will affect ash and sulfur specifications for particular uses in the future, and the future availability of coals to meet such specifications, are much too complex for discussion here. Sound decisions will have to be worked out for each specific case, depending on the technical and regional economic factors that are involved.

The United States has enormous coal reserves -- nearly one trillion tons of recoverable coal according to the latest estimate of the U. S. Geological Survey. This is equivalent to about 1900 years supply at the present rate of U. S. coal consumption. These reserves include huge tonnages of both low sulfur and high sulfur coals, of low ash and high ash coals, of coking and non-coking coals -- in fact, coals of all ranks.

However, the many grades and ranks of coal do not all occur in the same region, and freight costs limit the distance to which a given coal will be shipped. Purity specifications for coal for a particular use are not absolute values, but are instead strongly influenced by the nature of the coals that are economically available in the area, and the current status of the user's technology.

About 60% of the bituminous coal produced in the U. S. is mechanically cleaned, and the percentage is increasing. There is great activity in coal preparation research both in the U. S. and many foreign countries. The writer is confident that in the decades ahead, U. S. coal reserves will prove adequate in quantity and quality to meet the expected need for increasing tonnages of specification coal. Continued technological progress in the mining, preparation and use of coal will solve problems which may arise.

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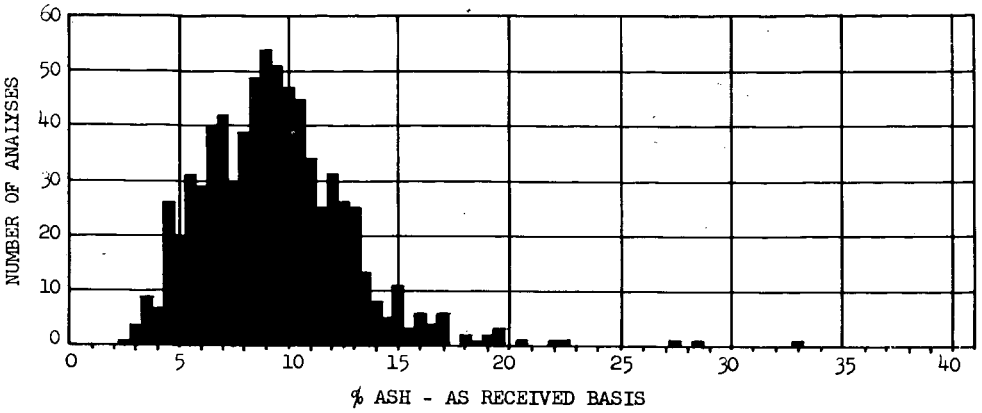

Fig. 1 - Ash Contents of Typical Coals of the United States, Including All Ranks. Analyses from Ref. 1 (1942)

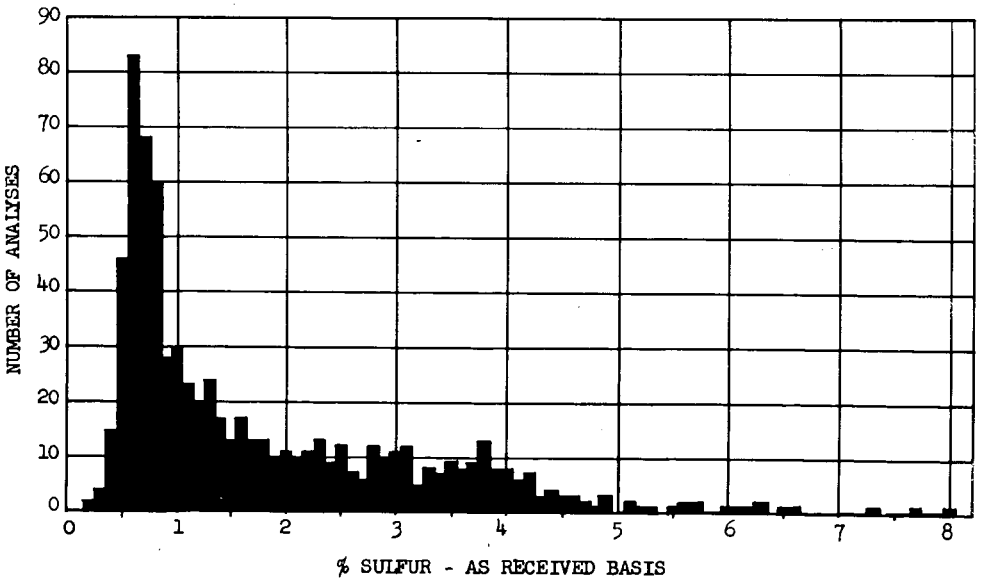

Fig. 2 - Sulfur Contents of Typical Coals of the United States, Including All Ranks. Analyses from Ref. 1 (1942)

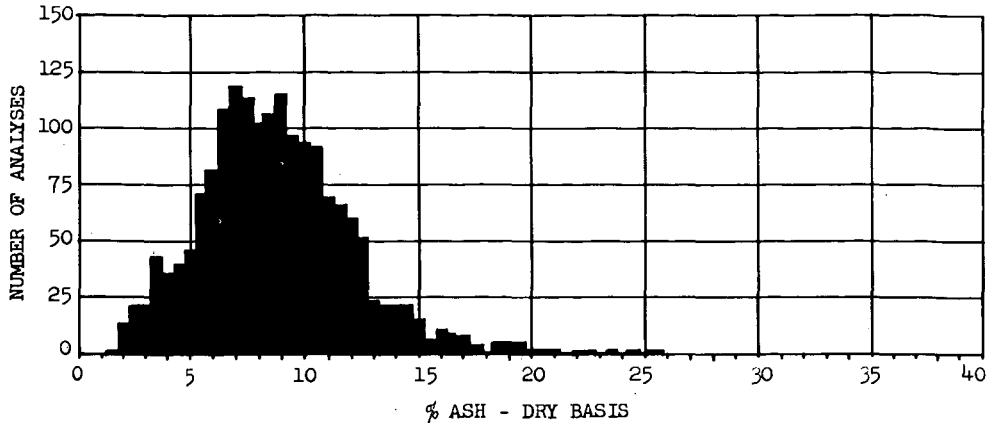

Fig. 3 - Ash Contents of Coals of All Ranks Purchased for Federal Government Use - 1956. Analyses from Ref. 2 (1957)

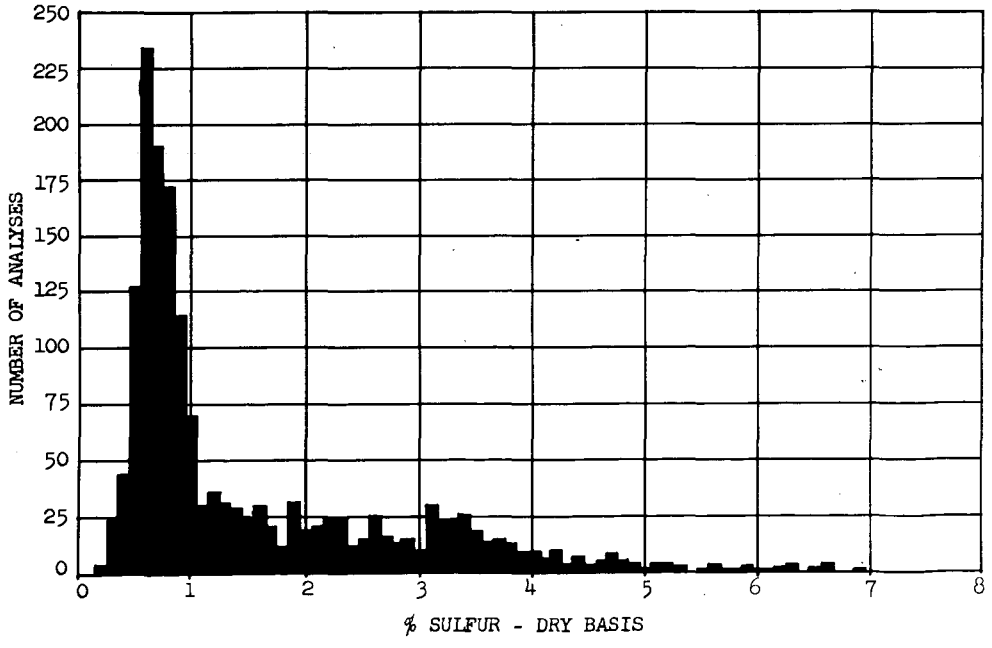

Fig. 4 - Sulfur Contents of Coals of All Ranks Purchased for Federal Government Use - 1956. Analyses from Ref. 2 (1957)

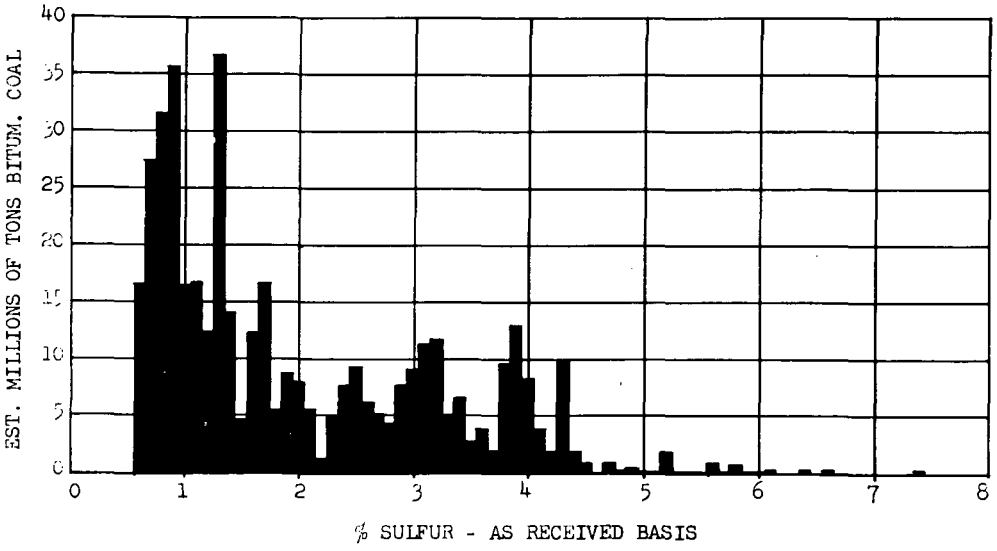

Fig. 5 - Estimated Tonnage of Bituminous Coals of Various Sulfur Contents Produced in the Eastern Half of the United States - 1953. Data estimated from Refs. 1 and 3

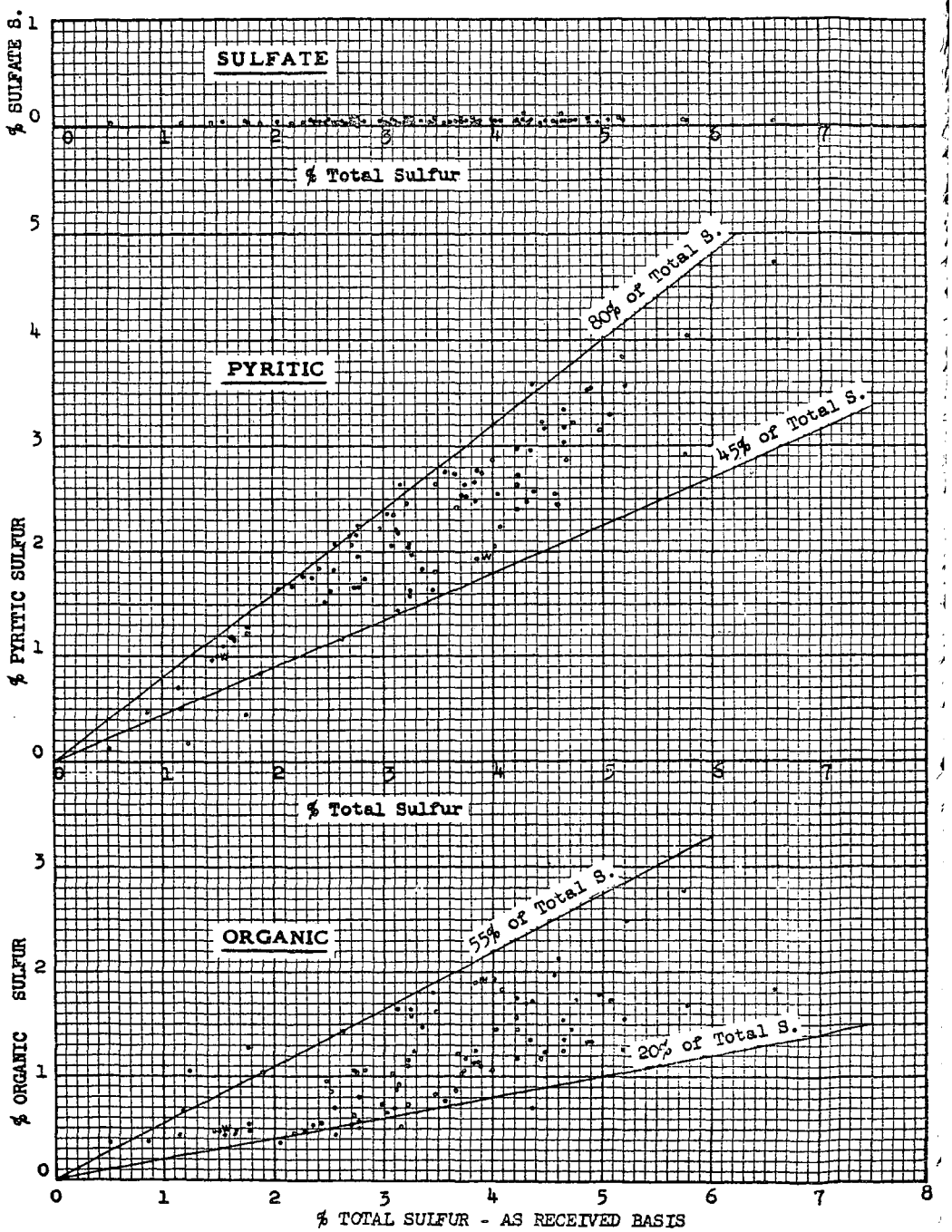

Fig. 6 - Sulfur Forms in OHIO Coals--Range in Organic, Pyritic and Sulfate Sulfur at Various Total Sulfur Percentages. Represents tipple samples from 16 counties and 9 coal beds. Analyses from Ref. 4

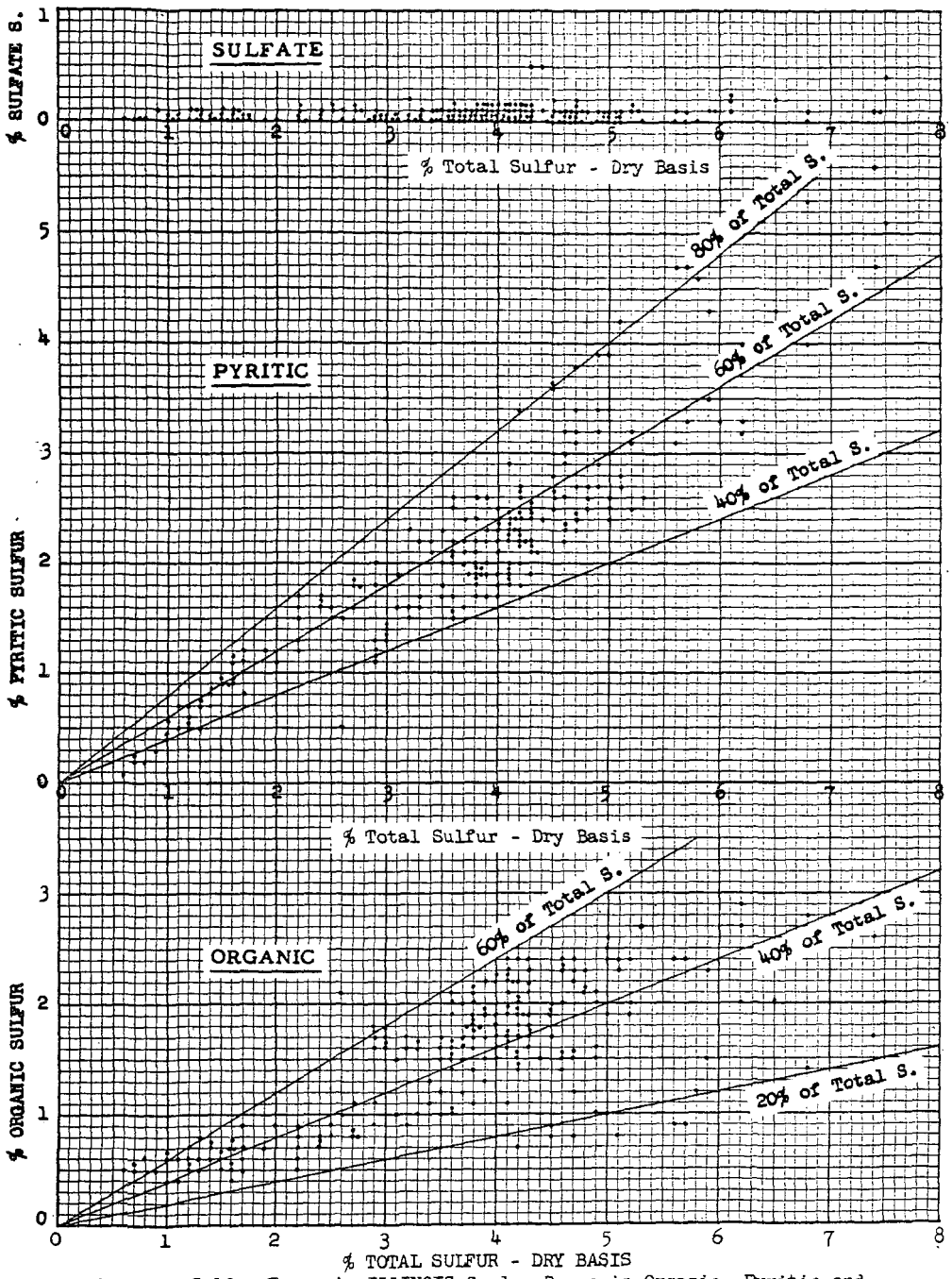

Fig. 7 - Sulfur Forms in ILLINOIS Coals--Range in Organic, Pyritic and Sulfate Sulfur at Various Total Sulfur Percentages. Represents face samples (some from inactive mines) from 36 counties and all commercially important beds. Analyses from Refs. 5 and 6